TITLE

**METHOD AND APPARATUS FOR DETECTING
SURFACE DEFECTS IN A PLASTIC CONTAINER**

5

TECHNICAL FIELD

This invention relates to a method and apparatus
for detecting and quantifying defects in a surface, and
more particularly to a method and apparatus for
10   detecting and quantifying stress cracks in a plastic
container.

BACKGROUND OF THE INVENTION

In many commercial markets, plastic containers such
15   as polyethylene terephthalate (PET), blow molded bottles
are designed to be returned to a bottle cleaning
facility and reused in the range of about twenty uses
per bottle. Over time, and as the number of uses
increases, PET plastic bottles develop defects such as
20   environmental stress cracks caused by excessive handling
and degradation of the bottle surface. Typically,
environmental stress cracks occur more frequently in the
base of the bottles, although environmental stress
cracks can occur at almost any location on the surface
25   of the container and may lead to failure of the
container during or after filling with a beverage.
Current methods used for detecting surface flaws or
defects such as environmental stress cracks in the
surface of a container can be unreliable.
30   An example of a method used to determine the level
of environmental stress cracking in returnable and
reusable beverage containers typically involves visual
examination by an operator with defect qualification
accomplished by comparing the sample to a uniform

1

standard and subjectively assigning a defect severity level to each container. Typically, a crack severity scale of 1 to 4 is used wherein a value of 1 indicates little or no stress cracking and a value of 4 indicates

5   severe stress cracking requiring the bottle to be discarded. Thus, current inspection has the inherent subjectivity of human inspection as well as requiring significant product handling.

    If, for example, quantitative data is desired for

10   statistical quality control, the location of defects and preservation of such data must often be obtained and preserved at an additional effort and cost. Visual evaluation is a difficult job and is very tiring for the eyes of the checking personnel, especially when articles

15   produced in large series have to be examined. Also, it is difficult to eliminate subjective influences from visual judgements.

    Another known method is the fluorescent crack detection method. The fluorescent crack detection

20   method requires that the container or article to be examined is first prepared so as to reveal the surface defects. The preparation typically consists of applying to the surface of the article a fluorescent or colored dye which penetrates into the openings of the defects on

25   the article surface, then removing the excess dye from the surface. The article is then exposed to electromagnetic radiation causing the dye which has penetrated into the cracks to fluoresce. The presence of the surface defects is then revealed by the emission

30   of a visible fluorescent light by the dye remaining in the cracks.

2

The florescent crack detection method requires the use of a dye and further requires the container being tested to be removed from a manufacturing or cleaning machine. It is therefore evident that improved systems and methods are needed for detecting defects at the surface of a container, and, particularly, in detecting defects at a surface of a returnable and reusable beverage container.

An object of the invention is to produce a plastic container stress crack detection system which uses ultraviolet radiation to determine the level of environmental stress cracking in a container.

Another object of the invention is to produce a plastic container stress crack detection system, which eliminates the need for a dye.

Another object of the invention is to produce a plastic container stress crack detection system, which can operate on-line and at a high speed during a container manufacturing or cleaning process.

Another object of the invention is to produce a plastic container stress crack detection system, which eliminates the subjective variations in detection resulting from visual inspection of a container.

A further object of the invention is to produce a plastic container stress crack detection system, which can quantify the level of stress cracking in a container.

Yet another object of the invention is to produce a plastic container stress crack detection system which minimizes production and cleaning costs.

3

Still another object of the invention is to produce a plastic container stress crack detection system, which minimizes product waste.

SUMMARY OF THE INVENTION

The above, as well as other objects of the invention, may be readily achieved by a method for detecting defects in a surface of a container including: providing a plastic container having a longitudinal axis and a surface; directing ultraviolet radiation from a source to the surface of the container; sensing a portion the radiation reflected from the surface of the container; and generating a signal from the sensed portion of the reflected radiation representing a defect in the surface plastic container.

The above method is typically achieved by a surface defect detection system comprising: a source of ultraviolet radiation; a plastic container having a surface; means for directing the container along a path through the radiation; detecting means for receiving a portion of the ultraviolet radiation reflected from the surface of the plastic container, and being responsive to generate a signal; and a computer means connected to the detecting means and being responsive to the generated signal for calculating a defect value, comparing the defect value with stored standards, and indicating one of acceptance and rejection for said plastic container.

BRIEF DESCRIPTION OF THE DRAWINGS

The above, as well as other objects, features, and advantages of the present invention will be understood from the detailed description of the preferred embodiments of the present invention with reference to the accompanying drawing, in which:

Fig. 1 is a perspective schematic view of the plastic container stress crack detection system incorporating the features of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to Fig. 1, there is shown generally at 10 a plastic container stress crack detection system incorporating the features of the invention. The stress crack detection system 10 includes a source of radiation 12 for emitting light energy, preferably within a range of from visible light to ultraviolet (UV) light, inclusive. The source 12 emits the visible to UV light radiation in the direction of a bottom surface 14 of a plastic container 16, such as a PET blow molded bottle. The source 12 is connected to a power source through a conductor 18. In the embodiment illustrated, the source 12 is a circular bulb, but it will be understood that more than one bulb of a variety of shapes such as tubular, may be used.

The stress crack detection system 10 further includes a detecting means know as a charge-coupled device (CCD) camera 20, such as an Allen-Bradley CVIM™, configurable vision input module, manufactured by Rockwell Automation, Rockwell International Corporation. The CCD camera is

disposed on the opposite side of the radiation source
12 from the container 16 for receiving the visible to
UV radiation from the surface 14 of the container 16.
A CCD is a light-sensitive integrated circuit within the
5   CCD camera 20 that stores the data for an image in such
a way that each pixel, or picture element, in the image
is converted into an electrical signal. Preferably, the
CCD camera 20 will have a minimum window size of about
480 by 480 pixels, and is capable of capturing image
10 data for objects moving a high speed, such as from about
two to about twenty objects per second. The CCD camera
20 is coupled to the power source through a conductor
22.

    The CCD camera 20 will preferably be positioned at
15 a distance from the container 16 so that the CCD camera
20 can optically observe the entire surface 14 to be
inspected. Preferably, the CCD camera 20 will be
positioned to optically observe an area of about 100
millimeters by 100 millimeters.

20   The CCD camera 20 provides an accurate and reliable
digital signal, and a sufficient current to drive a
shielded, low noise line 24, such as a twisted-wire
pair, or a terminated coaxial cable, to a computer 26.
The computer 26 is coupled to the power source through a
25 conductor 28.

    The container 16 to be detected for surface
defects is typically suspended in serial fashion from
a conveyor 30 having slots 32 for receiving a finish
34 of the container 16. The conveyor 30 will
30 typically travel at a rate to expose from about two
to about twenty containers 16 per second to the UV
radiation. In the embodiment shown, the containers

6

16 are caused to travel such that the visible to UV
light radiation from the source 12, and the CCD
camera 20 are directed toward the bottom surface 14
of the container 16. However, it will be understood

5 that the UV radiation and the CCD camera 20 may be
directed at any exterior or interior surface of the
container 16.

The plastic container stress crack detection
system 10 operates by directing the UV radiation

10 toward the surface 14 of the container 16. The UV
radiation emitted from the source 12 will pass
through a pristine portion, or portion of the surface
14 having no defects.

However, when the surface 14 is exposed to the

15 visible to UV radiation, defects such as
environmental stress cracks, scuffs, and nicks,
appear to be much lighter in color and of higher
light intensity than the pristine portions of the
surface 14. It has been shown that the effect of

20 defects appearing to be much lighter in color and of
higher light intensity is due to a greater amount of
light energy being reflected within or directed to
the defect than within the pristine portions of the
surface 14. Accordingly, defects such as

25 environmental stress cracks appear more intense when
exposed to radiation within the range of from visible
light to UV light than the pristine portions of the
surface 14 of the container 16.

The UV radiation reflected within each defect in

30 the surface 14 of the container 16 is optically
observed by the CCD camera 20. The electrical signal

7

generated by the CCD camera 20 is then introduced
into the computer 26 by the line 24. The computer 26
includes image processing software for generating an
image and performing several mathematical algorithms at
5   production line speeds. The algorithms performed by the
computer 26 may include algorithms to determine the
density of light present in a stress crack, and a
length, a width, and an area of a stress crack.

     A minimum size of the stress crack to be
10   observed can be determined by the following
equations:

$$l/p_1$$
$$w/p_2$$

15 where l is the length of the surface area of the
container 16 to be optically observed by the CCD
camera 20, w is the width of the surface area of the
container 16 to be optically observed by the CCD
camera 20, p_1 is the number of pixels corresponding
20 to the length of the window of the CCD camera 20, and
p_2 is the number of pixels corresponding to the
length of the window of the CCC camera 20.

     For example, if the CCD camera 20 is positioned to
observe an area of 100 mm by 100 mm, and the CCD camera
25 20 window size is 480 pixels by 480 pixels, then l/p_1 =
100 mm/480 pixels = 0.21 mm, and w/p_2 = 100 mm/480 pixels
= 0.21 mm . Therefore, it is understood that such a
system 10 can detect a stress crack having a length of
0.21 mm or larger, a width of 0.21 mm or larger, and an
30 area of 0.21 mm by 0.21 mm. It has been shown that
the system 10 is capable of detecting environmental

stress cracks having a width as small as about 0.10 mm.

The UV radiation data received by the CCD camera 20 is then processed by the image processing software of the computer 26, and the resulting image is displayed on a computer monitor 36. The computer 26 then compares the observed values, such as the calculated values representing the density of light present in a stress crack, and the length, width, and area of a stress crack with stored measurement standards. Based on the stored measurement standards, the computer 26 then accepts or rejects each container 16. The computer 26 may also display the inspection result on the computer monitor 34.

While mention has been made that mathematical algorithms will be performed by image processing software within the computer 26, it will be understood that similar results may be achieved by performing the mathematical algorithms within a CCD camera 20 having a suitable microprocessor and associated image processing software within the CCD camera 20.

The principle and mode of operation of this invention have been described in its preferred embodiment. However, it should be noted that this invention may be practiced otherwise than as specifically illustrated and described without departing from its scope.